Demo Abstract: Physical-layer-based Power Consumption Reduction in WSNs

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Abstract. A physical-layer-based power consumption reduction procedure is proposed, based on an advanced and reliable network planner with three energy-saving features: intelligent cognitive network planning, symbiotic network cooperation, and automatic transmit power adjustments. The optimization has been applied to and experimentally validated with a real-life wireless test environment and a power consumption reduction of 80% is obtained.

1 Introduction

Wireless sensor networks (WSNs) are increasingly being used for a variety of purposes. A crucial issue in the deployment of these networks is node and network lifetime and hence, the power consumption of the nodes. In this demo, a cognitive symbiotic network planner for power consumption reduction will be experimentally applied to a set of co-located independent wireless sensor test networks.

Symbiotic networks [1] are coexisting homogeneous (using the same technology, e.g., two independent Wi-Fi networks) or heterogeneous (using a different technology, e.g., cooperative Wi-Fi and UMTS networks) networks that cooperate over multiple network layers based on common incentives (shared network goals, e.g., a lower power consumption), through infrastructure and resource sharing. However, while striving to meet the agreed incentive, it is crucial that the network remains operational. Therefore, we have implemented an incentive-based symbiotic optimization algorithm into a cognitive indoor network planning tool. The proposed solution introduces a feedback loop between the planning tool and the actual deployed network, allowing to cope with inaccuracies of the used propagation models, to finetune transmit powers, or to adapt to a varying propagation environment or varying network conditions, as is the case when node failures occur. The network planner implements three energy-saving features: (i) intelligent cognitive network planning, (ii) symbiotic network cooperation, and (iii) transmit power adjustments.

2 Cognitive Symbiotic Network Planner

This demo will demonstrate a symbiotic physical-layer optimization of co-located wireless sensor networks, which is automatically controlled by means of a cog-

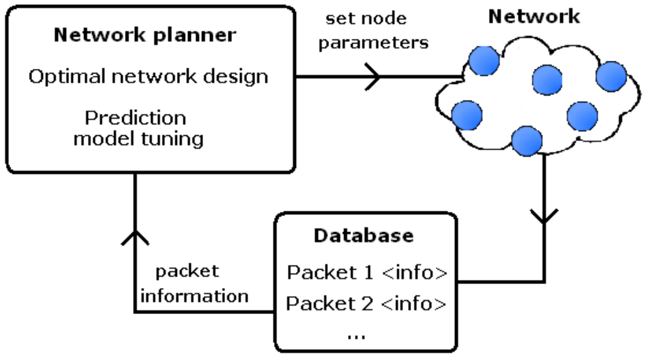

Fig. 1. Cognitive optimization process of wireless sensor network.

nitive feedback loop. These functionalities are implemented in a previously developed network planner [2], developed and validated for the prediction of path loss in indoor environments.

2.1 Network Planner Functionalities for Test Network

In this section, the different functionalities of the network planner will be illustrated: optimal sink selection, establishing symbiotic cooperation between networks, setting and optimizing node parameters, and path-loss model optimization.
Firstly, the network planner (logically) has the capability of optimizing wireless networks and is thus able to derive the number and location of the sinks (i.e., energy-consuming nodes that collect the data from the other nodes) using the coverage optimization algorithm described in [2]. For two independent sensor networks that have the common incentive 'lower energy consumption', the network planner could e.g., decide to reduce the total number of sinks, without affecting coverage. Secondly, the network planner is also able to establish a symbiotic cooperation between the different co-located networks, based on protocols on higher layers. Thirdly, the network planner is able to set the nodes' transmit/receiver mode on or off and to control the nodes' transmit power. And fourthly, the network planner can also tune its propagation models for more reliable predictions and hence better future decisions. These four features will be illustrated in Section 3, where they will be applied to a real-life wireless test network.

2.2 Cognition Implementation

Tuning of the propagation models and optimization of the node parameters is done based on a *feedback loop*. This cognitive network planning process is illustrated in Fig. 1.

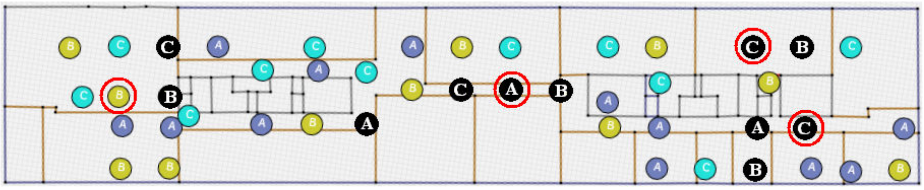

Fig. 2. Wireless sensor test network, originally consisting of three networks (A, B, C) (phase 1), their corresponding (optimal) sinks (black) (phase 2), and sinks after symbiotic cooperation (red circles) (phase 3).

The process begins with the *network planning algorithm* [2] calculating the sink locations. Then, the *network* (Fig. 1) is reconfigured in a second step and packets are sent accordingly. To determine whether or not the network behaves as expected, packet information (Received Signal Strength Indicator (RSSI), average noise floor, etc) is collected by the sinks and the measured data are stored in a *database* (Fig. 1). These data now serve as input for the cognitive planning tool: prediction models can be optimized and the transmit powers of the nodes can be finetuned.

3 Application of Cognitive Symbiotic Network Planner to Wireless Test Network

As a proof-of-concept, the cognitivesymbiotic network planner is applied to a real-life wireless test network (w-iLab.t) [3]. In total, 45 nodes, equipped with 1 or 2 TMoteSky sensor nodes have been installed in an office building in Ghent, Belgium. Fig. 2 shows the location of all the (operational) nodes of this wireless test network in the office building in which the w-iLab.t network is deployed. In four consecutive phases, different features of the network planning tool will be enabled in order to reduce the total power consumption.
Initially (**phase 1**), all 45 nodes are 'on', each of which consumes 65.01 mW, yielding a total power consumption of **2926 mW**. The nodes belong to three different sensor networks, indicated with a different color and a different letter inside the marker (A, B, or C, see Fig. 2). This is considered as the first of four phases between which consecutive power consumption reductions are executed.
After applying the network planner as a first optimization step (**phase 2**), the sinks for each network are determined (11 in total, marked with black dots (see Fig. 2). The other 34 nodes are assumed to have a duty cycle of 20%, to allow sending packets and detecting incoming packets. Under this assumption, the total power consumption of all 45 nodes will decrease to 1157 mW. In the demo, it will be shown that the adjustment of the prediction models in this phase, based on information obtained through the feedback loop (see Fig. 1), allows an improvement of the path loss predictions.
In the symbiotic phase (**phase 3**), symbiotic cooperation between the networks

is introduced. Based on sharing the infrastructure of the three networks and the finetuned path loss model obtained in phase 2, the incentive-based network planner designs a new network configuration, now with only four (shared) sinks instead of eleven for the original network (sinks circled in red, see Fig. 2). The independent networks A, B, and C cooperate and now form one symbiotic network, where each of the nodes sends its data to the corresponding sink. The symbiotic network has a total power consumption of **793 mW**.
The cognitive loop not only allows the tool to improve its network planning models, it also allows an individual optimization of the transmit powers in the symbiotic network for each sensor node (**phase 4**). The demo will show that knowledge of the receiver sensitivity and the link path loss fed back by the cognitive loop, allows calculating the minimally required node transmit power. With the assumed duty cycle of 20%, this leads to a total power consumption of **601 mW**, a total energy consumption reduction of almost 80% for the network under test.

4 Conclusions

A physical-layer-based reduction of power consumption in wireless sensor networks is presented and applied to an actual test network. Optimization is performed for multiple networks and over multiple network layers in a real-life testbed sensor network, based on actual measurements. Besides an optimal network planning including the adjustment of transmit powers, also a symbiotic optimization over different networks and network layers is implemented. Feedback about the signal quality parameters is used for optimization of the path loss models and for finetuning device transmit powers. The use of the network planner, symbiotic cooperation, and finetuning the nodes' transmit powers leads to a total power consumption reduction of 80% for the network under test. In the demo, these consecutive optimization phases within the wireless test network will be demonstrated.

References

1. E. D. Poorter, B. Latre, I. Moerman, and P. Demeester, "Symbiotic networks: Towards a new level of cooperation between wireless networks," *Special Issue of the Wireless Personal Communications Journal*, vol. 45, no. 4, pp. 479–495, June 2008.
2. D. Plets, W. Joseph, K. Vanhecke, E. Tanghe, and L. Martens, "Coverage Prediction and Optimization Algorithms for Indoor Environments," *EURASIP Journal on Wireless Communications and Networking, Special Issue on Radio Propagation, Channel Modeling, and Wireless, Channel Simulation Tools for Heterogeneous Networking Evaluation*, vol. 1, 2012. [Online]. Available: http://jwcn.eurasipjournals.com/content/2012/1/123
3. IBBT, "Ibbt - w-ilab.t," Website, http://wilab.atlantis.ugent.be/.